DAM INSPECTIONS

By Richard J. Baines[1]

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Introduction

In California, the Department of Water Resources has the responsibility for administration of the laws for dam safety. The Division of Safety of Dams is delegated this specific function. All dams, as defined in the Statutes for height and storage capacity, except dams owned and operated by the Federal Government, are under State jurisdiction. The authority of the law encompasses the dam, all appurtenant facilities and the reservoir - as related to safety.

With this broad responsibility for safety, the Division conducts many types of inspections: site inspections prior to construction, geologic investigations, construction monitoring and control inspections, periodic evaluations of operational dams, inspections for in-depth review of an entire dam or a specific feature, and special inspections in response to an unusual condition, incident or emergency.

The Division of Safety of Dams technical organization consists of three branches, Field Engineering, Design Engineering and Geology and special temporary units established for a specific task. The Field Engineering Branch is the program manager for all dams under construction and in certified status (operational) and is thus responsible for all but a few of the inspections. The Division technical staff is composed of civil engineers, many also possessing the geotechnical registration, and geologists and engineering geologists. The Field Branch has divided the State into three regions and the regions are composed of three areas, containing from 89 to 176 dams. The Area Engineer has the direct, first line oversight of the dams in that area and is generally assisted by another engineer.

This workshop[2] will focus on the more routine construction and operational inspections, aimed at monitoring the current status of a project or dam. Following my presentation, I will show a short video tape, condensed from the Training Aids for Dam Safety (TADS) material, that gives examples of inspection procedures, problem conditions and consequences.

Construction Inspections

Construction inspections have priority over operational evaluations and the contractor's schedule must be met for items that require approval. Our response time is no longer than 48 hours after receiving a request. Working with the project Resident Engineer to anticipate such a need usually results in no

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[1] Area Engineer, Division of Safety of Dams, Department of Water Resources, State of California, P.O. Box 942836, Sacramento, CA 94236-0001

[2] ASDSO Western Regional Meeting and Dam Safety Workshop, May 1-3, 1989, Sacramento, CA.

delay.

The Division of Safety of Dams maintains strict control over all foundations, for the dam proper as well as the appurtenant features, by inclusion of a clause in the contract specifications. Approval must be obtained from one of our field engineers prior to covering the foundation element in question. Under good working conditions, the Resident Engineer reviews the contractor's preparation until satisfied and then makes a recommendation for acceptance to the dam safety field engineer.

Inspections are made regularly and frequently for active construction projects, so the contractor, through the quality control personnel, has the proper objectives in mind. Weekly visits are not uncommon for a project that is not experiencing problems. This close attention is given to obtain the best assurance that the dam will perform satisfactorily. As stated by a former chief of the Field Engineering Branch in an orientation lecture, "You have only one chance to get the work done right - and in accordance with the approved plans and specifications."

As a regulatory body our supervision of construction activities is one level removed from the direct involvement of the Resident Engineer and his staff. The regulations mandate that the construction be under the direct control of a registered civil engineer. We work through the Resident Engineer to obtain the desired results. Our presence is not to gain popularity, but if we really want a good job we must be able to sell the concept of the importance of good workmanship down to the contractor's work force. Fairness and explanations of the objectives and the reasons for decisions help a great deal in obtaining that goal.

At certain intervals during construction, the design review engineer and geologists will be asked to accompany the field engineer on an inspection. Both are generally present to look at the foundation for the dam and cut-off to see how the foundation conforms to the design assumptions and criteria. Of course, when problems arise or changes are proposed, the design reviewers and geologists are consulted.

Problems can, and do, arise during the construction of a dam as they do on any project; however, the consequences can be far more serious for an embankment for a dam than, say, a highway. The first problems usually involve a foundation condition that was not revealed in the exploration for the design. Often the exploration is limited, especially in areas where access is difficult, like in the wet stream channel. Other common difficulties in embankment dams include water control, weak zones in the foundation, material problems, inadequate moisture conditioning, uneven lifts, poor compactive effort or pattern, imbalance of fill delivery equipment verses compacting equipment, keeping filter materials uncontaminated and ahead of the surrounding fill, disturbing the foundation prior to covering, air slaking, inadequate compaction at abutments and in confined areas, and falling behind schedule with the winter season approaching. Some of the listed problems are common to concrete dams and for the concrete structures associated with embankment dams. Problems can occur in concrete quality, placement and curing. One area we pay close attention to is concrete placement for the outlet encasement. The concrete is first deposited on one side of the conduit and vibrated until it flows underneath and part way up the other side, forming a cradle, thus insuring against a longitudinal void below the pipe.

Numerous photographs are indispensable for the records and a file of all negatives is maintained in

the office. Following every inspection is the report. The Division of Safety of Dams report form is entitled "Inspection Of Dam Construction" and is included in the appendix to this paper. The form is pretty basic and self explanatory. As a practice we describe in detail all the approvals that are given and highlight those in the Important Observations, Recommendations, or Actions section. Good, well-written reports are a great asset for future review and when you remember that you could be called to give testimony in a court of law where the statements will be examined and cross-examined.

Operational Inspections

Operational dams are inspected on a regular schedule based on their individual damage potential. A few low-hazard dams in extremely remote locations, such as in wilderness areas in the high Sierra Nevada mountains, are inspected once every two to five years. The individual Area Engineers make up their own schedule for inspections and it is good to vary the times of the year so the dams are seen under differing storage and seasonal conditions. The upstream faces of most dams are not visible during the late spring, but seepage that responds to reservoir level can be observed. Access may be restricted at times of the year due to snow or impassable roads, so those dams necessarily have a time span that is blocked out. From the above you can see that it takes a period of years for an Area Engineer to gain an in-depth knowledge of the dams in his or her area.

Prior to conducting an operational inspection, the engineer needs to be familiar with the history of the dam and the last few years' observations. The history of the dam is the general background information that explains the reasons for various features or treatment of past problems. The previous inspection reports reveal the current trends or conditions that need to be noted, like seepage areas and quantities at similar reservoir stage, ongoing problems, as well as to check on the completion or progress of requested actions. My practice is to review the file and as-constructed drawings and prepare a "tickler" file that contains items to note and previous conditions. I use the gummed post-it notes that can be stuck into my field book on the facing page. If the dam is more complex I will make a reduced photocopy of a plan so locations can be marked on the copy.

Equipment for the inspection varies but there are some basics: fieldbook, pencils, hand level, folding rule, probe, rock hammer, camera, flashlight, and a mirror. Special equipment may be needed such as binoculars, telephoto lens, flash attachments, 100-foot measuring tape, seepage measuring devices (bucket, portable V-notch weir), surveying equipment, boat, four wheel drive or all-terrain vehicles, carts for outlet inspections, etc. Personal equipment required is sturdy boots, long pants, hat or hard hat, watch, identification, and, as needed, rubber boots or waders, life vest, climbing safety gear, air monitoring devices and rain gear. Underwater inspections are conducted by certified divers. The Division does not presently have a team and it would be the owner's responsibility to arrange for such an inspection.

Division policy is to perform inspections with the owner or representative, when possible, making advance arrangements. The benefits of being able to discuss the findings of the inspection and the observations and actions with the owner are obvious. Additionally, time and expense can be saved when the requests can be made verbally rather than by formal correspondence. With the preparation complete, the inspection can begin.

The operational inspection involves a thorough walk-over of all of the accessible features of the dam, near abutment slopes and toe areas. Special attention is given to previously noted defects or areas of distress and any changed conditions. Notice of change is the single most important aspect of any inspection and then using engineering judgement to evaluate the consequences and necessity for action. Further comments on judgement and actions will be made when discussing the report of inspection.

The walk-over of the dam should be systematic so all the exposed features are viewed. Typically, on smaller dams, the crest and upstream face and slope protection, if any, is walked in a zigzag fashion from one end to the other. Then, descend one groin to the downstream toe and continue along the toe looking at the downstream face, toe and area beyond the toe. Again, the pattern is to walk up onto the face and out away from the toe looking at any irregularity, seeps, drainage system, vegetation or animal problem. On the crest, stop and inspect the outlet controls, walk down the upstream face along the control stem observing the slope, condition of the stem and its support and protection (from ice action in cold regions). If the intake is exposed, check the structure, trash racks and control valves. Similarly, at the toe look at the discharge end of the conduit and the surrounding embankment. If the end of the conduit is accessible use a flashlight or a mirror to look at the interior. The spillway is inspected from the approach to the return channel, and if discharging, the flow characteristics are noted. The reservoir perimeter and abutments are scanned for signs of instability. In other words, be curious, systematic, and thorough. Ask the owner/representative questions about any differences and about general performance.

There are other items to note for the record. The weather conditions are needed both at the time of the inspection and preceding it, if it has a bearing on the observations--such as ponded water at the toe of the dam following recent precipitation or snow melt. Look for changes in the surroundings, such as development below the dam or around the reservoir. Note the reservoir level and the past seasonal high if there was unusual runoff since the last visit. Comment on any releases, if pertinent. Get the name and title of the person contacted or accompanying you on the inspection.

Problems or defects that can occur in embankment and concrete dams are numerous. By far the most common or wide spread problems found in earth dams are undesirable vegetation and burrowing rodents and for concrete structures is surface deterioration.

The best vegetation cover for earthen dams is grass. Small trees and bushes are not a problem; however, they tend to grow quickly and then become difficult to remove or maintain. Trees, brush, and vines obscure the surface, allowing defects such as rodents, seepage, erosion and other distress to go undetected. In addition, certain trees and bushes have aggressive root systems that actively seek water. On the downstream slope, part of the root system travels upstream. When the plant dies the decaying roots form pipes that could lead to failure. The rest of the root system can invade drain blankets and clog collector pipes. If existing trees and bushes are large, they should be trimmed and topped to allow access to the slope and protect against being blown over by winds. When larger trees are removed, the roots must also be extracted. The backfill must be of suitable material and correctly compacted. Not only should the dam be maintained clear of objectionable vegetation but also five feet or so onto the abutments and toe areas as well as around any drains, the outlet, and near concrete structures. Of course the spillway, the approach and the downstream channel or chute needs to be kept clear. Certain native low-growing shrubs are tolerated and must be well spaced. Landscaping with

ivy or ice plant that requires irrigation is discouraged because of fast thick growth, cover for seepage and encouragement toward slope instability. Concrete dams are not immune from vegetation problems. Growth in joints, behind walls, in drain and weep holes can cause movement, spalling and increased water pressures.

Burrowing rodents can be extremely detrimental to an embankment and must be controlled. These pests need to be eradicated and their burrows refilled with compacted, moisture-conditioned fill material. It is important to backfill the holes as this discourages reinfestation and any new activity is easy to detect. There are many methods of control that vary with the type of pest and location. This is a matter that should be addressed on an individual case basis. Other rodents have, at times, caused difficulties such as beavers constructing obstructions in spillways, outlet channels, or near drainage outfalls. Large animals like, cattle, sheep and horses, walking along or going up and down the slopes create paths or trails that concentrate water and displace slope protection, leading to erosion.

The other defects that can affect embankment structures can be much more serious than vegetation and rodent problems, and are such things as longitudinal, transverse or desiccation (or shrinkage) cracking. Longitudinal cracking can be symptomatic of uneven settlement or slope failure or slipout. Transverse cracks can indicate differential settlement caused by steep abutment slopes, yielding foundation, or a sharp grade change in the abutment. Pay close attention to cracks, noting their location, width, depth and length. Rainfall entering larger cracks can exacerbate the condition. Instability can manifest itself in slides, deep seated or shallow, and bulging. Depressions and sinkholes can be formed by local settlement, embankment spreading or piping. Surface erosion on the upstream face can be from wave action on inadequate slope protection and runoff above the reservoir level. On the downstream face surface runoff can be channeled by cracks and animal activity to cause gullies. The groin areas are particularly susceptible to concentration of flow. Damage to the upstream face and/or slope protection and spillway obstructions are the next two most prevalent deficiencies encountered on embankment dams, followed by seepage problems.

Obstructions to the spillway might be debris and some sort of floating boom in the approach is the solution. Raveling, sliding and rockfalls from steep abutments, beaver dams, unauthorized barriers and vegetation are other forms of obstructions. Have these cleared immediately or before the reservoir is expected to spill.

Seepage is present at all but a few wide low dams and then it may disappear into the foundation not to surface in the vicinity of the dam. Seepage that is controlled by internal drains or foundation drains is not generally a concern. This seepage has been anticipated and has a designed collection system. The quantities of seepage and appearance of the water need to be observed and evaluated with the flow history. Changes alert the engineer that something could be happening. Decreased flow may indicate plugging of the filter material or the drain outfalls. Increased flow could signal internal piping and higher pressures in the dam, which lowers the stability. Uncontrolled seepage that emerges from the fill, abutments or foundation must be carefully monitored. Flow rates or the size of damp areas must be recorded for consideration of any necessary action. Seepage is prone to the groin areas and around the outlet and spillway structures. These areas are difficult to compact and the foundation may be somewhat porous. Seepage usually is associated with the reservoir, but the natural abutments can deliver ground water to the interface with the dam or into the dam itself, if the downstream shell is relatively free draining or contains lenses. Foundation seepage emerging

near the toe can carry silts and sands forming a boil at the exit point. Piping is occurring and this is a serious condition. Treatment is necessary. Any time turbidity is observed the source needs to be discovered. Internal piping is the danger. Siltation in seepage areas or measuring weirs may be from surface flows. If there are measuring devices, like weirs, it is not so important that the weirs be accurate as it is to have consistent measurements so that differences can be noticed. Again, for the report, locate, photograph and record the observations. When photographing features, try to include some object to give the photograph some scale, like a folding rule, or a person, or your fieldbook.

For concrete dams and structures in general, check the surfaces for deterioration from age and weathering, for structural cracking caused by overstress from applied loads shrinkage or differential movements. Check for movement along vertical and horizontal axes, and along joints. Assess the condition of the abutment contacts and the abutment for instability or excessive weathering. See that the drains are functional and performing as designed. Look at concrete outlets for abnormal leakage, erosion, cavitation, obstructions or significant cracks. If accessible, examine the foundation for undercutting at the downstream toe. This may require dewatering or a diving team at a special inspection. Seepage and leakage observations are the same as for embankments.

For spillways with gates, inspect the structural members and connections. Also, the hoists, cables and operating equipment, including backup or auxiliary devices. If there are drop-in gate panels or flash boards, verify the availability of equipment to handle their removal under active storage.

Outlet operability should be confirmed. This can be by observation that releases are being, or have been made. Our policy is to request owners to exercise their valves or gates, full cycle, once, and preferably twice, a year. For those dams where there is a question, we ask to observe the operation about every five years. This is done at the owners convenience by prior arrangement.

A final item to review during the inspection is the observable condition of any instrumentation. Check monuments for signs of disturbance, open tube piezometers for locking vented caps, any gages for appearance, weirs etc. for debris, siltation leakage bypass, and security of other devices. If drainage collection systems have alarms, look at their settings and question testing them.

Now that the inspection is completed, go over your findings with the owner/representative, even if you have done so as you progressed, to make clear what actions are required and if the actions are definite or tentative. It may be that a follow-up letter will be necessary or requested. This is the time to obtain some general information on changes of ownership or staff, changes in the normal operation of the dam and reservoir and ask about any unusual events since the last inspection. Also, take some time to sell the importance of regular maintenance and observation. The owner is the beneficiary of the project and has a substantial investment when calculated at today's replacement cost. Explanation of the reasons for your requests goes a long way in obtaining cooperation. Finally, I tell them that we are available to assist them, to answer questions concerning their dam and to please notify our office of any unusual occurrence or condition.

Following the inspection, a report is prepared containing all the factual observations, conclusions, recommendations and comments, plus photographs, sketches and other pertinent information. The

report is at least as important as the inspection. I won't go into details of report writing, but remind you that, as mentioned for the construction report, the report is a legal document which must withstand scrutiny at a future date. Analyze the findings of the inspection before writing the report.

The form used by the Division of Safety of Dams is entitled, "Inspection Of Dam And Reservoir In Certified Status". A copy of this form is in the appendix. The form is self-explanatory and fairly unstructured. By that I mean that the report is not a check list. Policy is to comment on all the features that were observed, both positively and negatively, as well as mentioning what was not reviewed. On the back of the form is a list of numbered items to use in the report. This organizes the reports into a set pattern, which facilitates review.

The section for important observations, recommendations or action taken is for summarizing results. These summarizations are supported in the body of the report.

In the body of the report, compare the present observations with those of past inspections. Make statements about defects whether they are stable or progressing. Compare instrumentation records and seepage observations to see if they are within the anticipated or design limitations. State the source of the facts in the report. If they are your own observations, say so. If the information is second hand, identify that source.

Conclusions are fairly basic. The dam is judged to be: 1, satisfactory for continued operation; 2, satisfactory for continued operation with some qualifying statement, like being subject to the review of some aspect (i.e., seismic stability); 3, satisfactory as operated at a restricted level; or 4, unsatisfactory. For legal protection to limit liability for what is concluded, it is important not to state that the dam "is" satisfactory but is "judged" safe or satisfactory and to state the basis for the conclusion. Management has instructed the engineers to discontinue using the word "safe", substituting "satisfactory" in our conclusions. We use wording as follows: "Based of the available information and the visual inspection, the dam, reservoir and appurtenant structures are judged satisfactory for continued use."

The laws governing dam safety are equal in treatment of all dams, including requiring corrective action. It is the engineer's responsibility to use judgement in assessing the severity of a deficiency, and what time schedule for rectifying the situation is reasonable, taking into account the damage potential. The damage potential is based on the size of the dam and reservoir, the estimated population that would have to be evacuated and the estimated monetary loss to property from a failure. However, should the integrity of the dam be threatened, immediate response is ordered.

In conclusion, the inspecting engineer's eyes are the best instrument for reviewing the current status of a dam and reservoir and his brain is the best computer for analyzing the results. Remember to look at everything on and around the dam and question anything that is out of the ordinary or changed. Take lots of notes and photographs and adequately document the findings.

This paper is greatly condensed. Information for inspections fills volumes when explained in detail. Some items have been undoubtably overlooked, but I trust the major areas have been mentioned.

Appendix

1. Inspection of Dam Construction, DWR Form 624

2. Inspection of Dam and Reservoir in Certified Status, DWR Form 1261

References

1. Internal documents and files of the Division of Safety of Dams.

2. U. S. Department of Interior, Bureau of Reclamation. Safety Evaluation of Existing Dams.

3. U. S. Department of Interior, Bureau of Reclamation. Training Aids for Dam Safety Modules.

State of California
The Resources Agency

DEPARTMENT OF WATER RESOURCES

DIVISION OF SAFETY OF DAMS

INSPECTION OF DAM CONSTRUCTION

Name of Dam Dam No.

Contact Made County

Stage of Construction

Important Observations, Recommendations or Actions

Conditions Noted and Remarks

Inspected by _____
Date of Inspection _____
Date of Report _____
Photos taken ? Yes ___ No ___

DWR 624 (sub) (2/24/95)

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES
DIVISION OF SAFETY OF DAMS

INSPECTION OF DAM AND RESERVOIR IN CERTIFIED STATUS

Name of Dam _____ Dam No._____ County _____
Type of Dam _____ Type of Spillway_____
Water is _____ feet _____ spillway crest and _____ feet _____ dam crest.
(above,below) (above,below)
Weather conditions _____
Contacts made _____
Reason for inspection _____

Important Observations, Recommendations or Actions Taken

Conclusions

Observations and Comments

Item No.*	Item Name and Observation and Comment

FIELD SHEET KEY ITEMS

Typed by _____
Date _____
cc for _____

*Use Field Sheet Standard Numbers and Items (See Reverse Side)

Inspected by _____
Date of Inspection _____
Date of Report _____
Photos taken? Yes ____ No ____

No.	Item
A1	Embankment Dam-Upstream Face
A2	Embankment Dam-Downstream Face
A3	Embankment Dam-Abutment
A4	Embankment Dam-Crest
A	Embankment Dam-Galleries
B1	Concrete Dam-Upstream Face
B2	Concrete Dam-Downstream Face
B3	Concrete Dam-Abutment
B4	Concrete Dam-Crest
B5	Concrete Dam-Galleries
6	Approach Channel
7	Stoplogs
8	Control Structure of Spillway
9	Spillway Gates and Controls
10	Spillway Chute or Tunnels
11	Spillway Energy Dissipater
12	Intake-of Outlet
13	Outlet Conduit
14	Control Facilities of Outlet
15	Outlet Energy Dissipater
16	Outlet Channel
17	Seepage and Drainage
18	Instrumentation
19	Reservoir
20	Access Roads
21	Other

List deficiencies and what will be or has been done to correct them - Refer to letters, on-going studies.

Make a statement as to Safety. If the dam has unsafe condition, restriction of storage should be recommended.